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The Σn=n Concept

And the Quantitative Support for the Cerebral-Holographic and Electromagnetic Configuration of Consciousness

Abstract: *The concept of the Σn (the sum of n) = n can be considered a description of the holographic condition. We present systematic calculations of the quantitative convergence between the electromagnetic and related physical properties of the plasma cell membrane and its ion channels with those of the entire cerebral volume. The thickness and fundamental frequencies of the cerebral cortices reflect both space and time constants of the unit neuron and are congruent with the traditionally postulated re-entrant processes coupled to consciousness. The essential wavelengths and densities of the whole cerebrum can be viewed as identities with those of single action potentials and photon fields. The energy generated by consciousness-associated neuronal electromagnetic activity can be matched by applying weak transcerebral magnetic fields. Matrices of 'punctuated' fields whose configurations approach the width of synapses and whose angular rotations move with tensor-like patterns around cerebral space might*

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be employed to experimentally manipulate the holographic condition by direct field-to-field interactions.

Key words: hologram, cerebral cortical fields, quantum relations, neurophysics, biophysical convergences, the whole equals the unit

Introduction

The source of the 'binding factor' for consciousness has been a focused pursuit for several authors (Llinas *et al.*, 1998; Persinger, 1999a; Engel and Singer, 2001). We suggest there is more likely a family of factors. One of them is an emergent property shared by all neurons and represented within the aggregate that constitutes brain space and its electromagnetic properties. An essential locus of this factor is within the space occupied by the neuronal plasma membrane. We are proposing that the electromagnetic information that is mapped onto the cell membrane, with participation from the channels, is represented reciprocally within the electromagnetic field of the entire cerebral cortices. The formal description of this relationship is $\Sigma n = n$, that is the magnitude of the value for the whole is equal to the magnitude of the unit.

If this approach is valid then physical quantities that exist at the level of the membrane and are responsible for microelectromagnetic changes should be within the same order of magnitude as those that define and characterize the whole: the cerebral cortices. This condition would meet the criteria for a hologram where every 'part' is distributed over the whole and every part therefore contains the whole. According to the model of Pribram and Meade (1999), information processing, from which consciousness emerges, is more similar to Gabor wavelets than to binary sequences, although there is the possibility of a mathematical convergence between the two within, for example, Hilbert space (Persinger and Koren, 2007; Koren and Persinger, 2010). Gabor wavelets are considered the bases of the interference patterns, as a result of refracted waves and a coherent background wave, that store both amplitude and phase (Pribram, 1971). One possible neurobiological equivalent might be the interference 'waves' produced by myriad action potentials superimposed upon the coherent steady potential background wave like that associated with microstates (Koenig *et al.*, 2002).

The definition of information as 'an intrinsic, irreducible and nonlocal property of the universe, capable of generating order, self-organization, and complexity' (Di Biase and Rocha, 2000) may minimize

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the apparent antagonism between wavelets and BITs. The antithetical position of a unit (a bit) versus a process (a wave) is more likely to be analogous to the apparent contradiction that existed for light as a particle or wave. If becoming aware of our conscious experience is due to the delay of an incoming pattern before it is matched with a previously established structural pattern of organization ('memory'), as suggested by Pribram and Meade (1999), there would be little contradiction. In fact it would accommodate the simultaneous representation of the modal frequency (40 Hz) associated with consciousness upon the slower theta (5 to 7 Hz) waves associated with memory consolidation within the hippocampus (Lisman and Idiart, 1995). This coupling has been measured at very global levels where theta-gamma phase synchronization occurs during memory matching (Holz *et al.*, 2010).

Consciousness, if it is not analogous to phlogiston in the context of modern chemistry or the *elan vital* for modern biology, is the emergent phenomena either caused by or strongly correlated with the electromagnetic properties of the human brain. Such a statement is compatible with the simultaneous importance of neurochemistry in the essential formulation that structure dictates function but would not eliminate, in a manner similar to the dual display of wave and particle properties for photons, the simultaneous existence of electromagnetic equivalents to these patterns of synaptic matter. McFadden (2002a,b) has developed both qualitative and quantitative arguments that consciousness may be an electromagnetic field. We appreciate the caveat by Cabanac (1996) that consciousness might be multiple phenomena.

From our perspective the cerebral electromagnetic field's complexity, which has been considered to be a major condition for consciousness (McFadden, 2002a), would be generated from or correlated with the essential spatial increments within space. This space is the synapse (particularly the spine-related synapse) of which there are approximately 10^{13} in the human cerebral cortices (Shepherd, 2004). They would be constitutional candidates for Eccles' dendrons (Eccles, 1992) and the presynaptic web. The quantitative values for this spatial increment would be between 0.5 and 2 μm, the width of a synapse, as well as the traditional depth of a node of Ranvier. If this range in width were considered electromagnetic wavelengths (500 nm to 2000 nm) they would overlap with the visible and near infrared frequencies of photons.

There would be extraordinary complexity within the topologically continuous electromagnetic field generated within the microspaces *surrounding* these synaptic (spine-related) interfaces. It would be analogous to what is measured by the 'zorro' method, a variant of

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diffusion tensor imaging (Tuch *et al.*, 2002) for quantitative measurements of tractographic representations. As suggested by Di Biase (2009), memories and consciousness would be represented within, in addition to synaptic patterns, the holographic information field that surrounds them.

In this paper, we present quantitative evidence that fundamental quantities for the physical properties of the neuronal cell membrane also define the whole of the entire cerebral cortices. These properties are in turn related to fundamental quantities of matter, particularly the Bohr magneton, and the probabilistic patterns associated with the quantum characteristics of matter and energy. Within cerebral space consciousness might be described by wavelet-like patterns containing Gabor's quanta of information which involves mathematics similar to Heisenberg's application to microphysics (Di Biase, 2009). If quanta are involved they should be discrete values coupled to known or measureable physical properties within the volume occupied by the cerebrum. Because the supportive arguments are quantitative solutions, the detailed presentations of the process to obtain these solutions were considered important.

Optimal Quantitative Properties of the Cerebral Cortices

Most neurobiologists have assumed that the membrane is a fundamental correlate to the functional integrity of the cell. The selective permeability allows the maintenance of a potential difference (voltage) that may even define one aspect of 'life' or 'vitality'. From the perspective of microcosm reflecting microcosm, a concept compatible with the hologram or the gnomon (Gazale, 1999), the fundamental characteristics of the membrane should be directly reflected in the properties of the larger whole: the cerebrum.

Indeed the congruence exists for both cortical space and time. The plasma membrane determines the time constant of the cell which is the time required for a constant current pulse to charge the membrane capacitance to $1\text{-}1/\varepsilon$ [where $\varepsilon = 2.718$, the value from $1 + \Sigma(1/n!)$] or about 63% of the final value. The time constant affects temporal summation. It can be defined as the process by which consecutive synaptic potentials at the same discrete locus are added within the postsynaptic cell that will determine if an action potential occurs or does not occur.

The quantitative value for the time constant is by convention the product (* will indicate multiplication) of the capacitance and resistance of the membrane. If the former is in the order of 10^{-6} F/cm^2 and the latter is 10^5 ohm cm^2 the time constant would be 10^{-1} s (100 msec).

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The frequency equivalence is 10 Hz, which is the most dominant increment for the peak of the power output for the cerebral cortices. The appearance of the normal distribution (assuming a standard distribution of about 30% of the mean) of the dispersion around this peak would be between 7 Hz to 13 Hz. This range is the classical alpha rhythm band and theta-alpha interface. This is a primary transition for a variety of states including Stage 0 to Stage 1 and potentially Stage 2 (light sleep) in electroencephalography. Consequently, the characteristic of the unit (the neuronal-axonal membrane) is reflected in the properties of the whole.

The approximately 100 msec (80 to 120 msec) interval is also the range within which stable transcerebral electrocortical patterns occur followed by rapid configurational changes (Koenig *et al.*, 2002). These recursive configurations manifested primarily as four spatial polarized patterns along the cerebral rostral-caudal axis and are relatively stable across the person's life time. Two of these polarized patterns cross diagonally (and in opposite directions) into the opposite hemisphere. The duration of these 'microstates' match the minimum duration of a percept (Efron, 1970) and may correspond to the basic units, in a manner similar to the base nucleotides' relationships to DNA sequences, of human information processing (Lehmann *et al.*, 1998).

Such changing but continuous sequences of configurations would be consistent with Gabor-like wavelets that constitute quantum holographic vector fields. According to Pribram and Meade (1999), the metaphorical flow of information in the brain would be vector fields created by temporary dominant foci of fields of electrochemical activity. The identification of the discrete range in the temporal durations and spatial organizations of microstates yields physical dimensions that might allow more precise definitions of consciousness as well as its mathematical description and experimental modification.

The plasma membrane also determines the space constant. This is the distance from the soma membrane where the perturbation in the electromagnetic field current diminishes to $(1\text{-}1/\varepsilon)$ of the initial (highest) value at the axon hillock. The space constant for an average axonal width of 1 μm (10^{-4} cm) would be the square root of the product of this value multiplied by the membrane resistance (10^5 ohm·cm^2) divided by the resistance of the axoplasm (50 ohm·cm). With these values the space constant, which again would show dispersions concordant with the range in axonal widths and membrane resistances, is about 4 mm.

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This length approximates the typical depth of the cerebral cortices (Blinkov and Glezer, 1968). One of the most conspicuous features of the evolution of the mammalian cerebral cortices is that the thickness has remained relatively constant or stable while the surface area has increased markedly in association with the greater capacity for information processing and representation. This cortical depth 'constancy' may have been constrained by the basic parameters of the membrane's time and space constants. As a result the quality of information processing and consciousness may not have changed but their magnitudes may have been enhanced significantly within the mammalian brain. Individual units with smaller aggregates ($\sim 10^6$ neurons), such as hymenoptera, might approach some analogue to consciousness as a group if very large numbers of individuals were immersed within the same 'connecting' medium.

For the holographic condition to be satisfied the functional unit and whole should share an identity. For example, the relationship between an average 1 μm diameter for an axon and 4 mm space constant (and depth of cerebral cortices) should also be related to the intrinsic voltage of the cortical volume. The area of a single axonal equivalent with these parameters within the cortices would be $2\pi*r*h$ or 1.26×10^{-2} μm^2. Assuming 10^3 to 10^4 functioning ion channels/μm there would be between 1.26×10^1 to 1.26×10^2 channels per axon barrel.

Assuming 10^{10} functioning axons in the cerebral cortices, there would be about 10^{12} channels. With temporally discrete movement of $\sim 10^6$ ions per sec per channel, there would be a total of 10^{18} ions during functional increments of time. The total current per sec from a unit charge of 1.6×10^{-19} A·s would be about 10^{-1} A. Applying the traditional equation for voltage which is current divided by resistance, where the latter is about 30 ohm·mm, a first order estimate of the averaged 'steady state' voltage would be between 1 to 10 mV. This is within the range of empirical observation for surface cerebral cortical 'steady potential' fields.

The frequency equivalence of an electromagnetic wave with a wavelength of 4 mm would be 3×10^8 m/s (c, the velocity of light) divided by this value or 75 GHz (0.75×10^{11} Hz). The energy (J) associated with this frequency is Planck's constant (6.6241×10^{-34} J·s*0.75×10^{11} Hz or 4.97×10^{-23} J). The mass equivalent, assuming c, for this energy is 0.55×10^{-39} kg (or 10^{-36} g) which is well within the range of the upper limits of the resting mass of a photon (Tu *et al.*, 2005). It may be relevant that the phase shift ($t/([v^2/t^2]$) for the predicted discrepancy from c (*ibid.*) for radiofrequency ranges would be in the order of 20 to 25 msec, which is the Δt (base increment of time)

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for a major theoretical and empirical candidate for the '40 Hz' re-entrant processes associated with consciousness. One interpretation of this phase-shift solution is that consciousness is 'temporally displaced' from its cerebral sources by that duration.

The convergence at this quantized value (or more likely range of discrete values) for mass with energy also sets the condition for holographic processes. This discrete range in wavelets is central to the coherent alignment and oscillations between 10^9 to 10^{11} Hz that occur among cells and supports the concept of cooperative quantum effects (Fröhlich, 1968), a presumed biological analogue of the Bose-Einstein condensate, where the units converge to a whole and the whole behaves as a unit. The frequency of 'thought' carrying particles (De and Pal, 2005) has been calculated to be in this range, i.e. 7.5×10^{10} Hz.

The recent measurements (Tu *et al.*, 2005) and strong inferences that photons exhibit non-zero mass that alter with frequency and velocity have significant implications for neuroscience and the study of consciousness. These possibilities include the existence of *longitudinal* (in addition to the traditional transverse) electromagnetic waves, deviations from exactness in Coulomb's and Ampere's laws, and the addition of a Yukawa component to the potential of magnetic dipole fields. The competition between this potential and magnetic dipole-dipole interaction allows colloidal liquids (states such as the plasma membrane) to become anisotropic in the presence of weak magnetic fields, including geomagnetism.

The temporal congruence between the time required for a photon to traverse a 10 nm neuronal membrane and the time (10^{-16} s) required for one orbital rotation of a Bohr electron are effectively identical or certainly within the range for intermittent congruence or resonance. The value of 10^{-16} s for the rotation of an electron once around its orbit is based upon the fine structure velocity (1/137 c) which is derived exactly from the relationship between $F = m(v/s)$ and Coulomb's Law: $F = e^2/(4\Pi e_o r^2)$ from classical physics (Halliday and Resnick, 1962). Direct measurements also indicate that the time required for an electron to move from one atom to another is between 1.5 and 3.2×10^{-16} s.

Theoretically, this would allow information associated with that photon to be represented within the completion of a singular orbit (1 cycle) of an electron in a Bohr atom. The unit characteristic for a single orbit of an electron defines the Bohr magneton which has a value in the order of 10^{-24} $A \cdot m^2$ which is the equivalent to J (energy) per Tesla (applied magnetic field strength). It is a fixed quantity for the magnetic moment of an electron due to the circulatory current created

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by the angular momentum of movement through the orbit. A variant value (Persinger *et al.*, 2008) derived from these quantities also closely approaches the value for Planck's constant. It is the energy equivalence of an electron mass moving at the fine structure velocity for the duration of one orbit (10^{-16} s). This is the same order of magnitude for a photon moving at c to traverse a 10 nm width of a plasma cell membrane an therefore allows a potential coupling between photons and the essential matter (the proton and electron) that compose the membrane condition with which consciousness is strongly correlated.

That photons are important correlates of neuronal activity has been argued by Popp (2003) who showed that living systems emit photons within the near ultraviolet, visible, and near infrared range at about 10^6 to 10^7 photons/s/m^2. In rat hippocampal preparations the output of biophotons is in the order of 10^{-12} W/m^2 and is coupled to the amplitude of theta activity (Kobayashi *et al.*, 1999). Photon emission from the human brain, particularly the right hemisphere, is associated with *qualitative* shifts in thinking (Dotta *et al.*, 2011; 2012). The energies were equivalent to 10^{-12} J/s and would involve about 10^7 cerebral cortical neurons.

The functional coupling between photon emission from the brain and its activity would be an important condition to support holographic consciousness. Bókkon (2005) suggested biophotons may be central to informational processing within the brain and that the content of conscious experiences during dreams and wakefulness may actually be derived from organized matrices of these photon fields. He further demonstrated (Bókkon *et al.*, 2010) by combining exact calculations with contemporary data, that the numbers of biophotons inside neurons are significantly greater than the outside. This hypothesis was recently supported by Sun *et al.* (2010) who showed by *in situ* biophoton autography that biophotons behave as neural communication signals, and by Wang *et al.* (2011) who measured spontaneous and evoked photon emission from retinal tissue.

Convergence of Cortical Columns and Quantum Energies

There should be congruence between the energy of the primary unit, the action potential, and the primary functional aggregate, the cerebral cortical column, associated with consciousness. Wei (1969) showed that the energy exerted by a net change in voltage of 120 mV (1.2×10^{-1} V) from an action potential upon a unit charge of 1.6×10^{-19} A·s was ~2×10^{-20} J. This was equivalent to the energy required to

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stack one base on a RNA 'ribbon' within about 1 msec, the duration of the action potential. Over three decades ago this was considered one means by which the transient patterns of neuronal EM phenomena could influence protein structure and hence memory representation within brain space. By modifying the base sequence of RNA in a specific sequence, depending upon the presence or absence of an action potential per 1 ms, particular sequences of amino acids (proteins) would be subsequently synthesized. These sequences of proteins contained within emergent dendritic spines or related specialized membrane processes about 1 ksec following the patterns of axonal stimulation *are* the memories from a neurochemical perspective.

Persinger (2010a) expanded that concept to show this quantum value (~10^{-20} J) emerged: 1) at the average distance between charges on the surface of the membrane that creates the membrane potential, 2) when the force of atomic bonds, particularly covalent forms, are distributed over interatomic space, and 3) as the average energy for the total numbers of molecules in a cell. The 'quantum' of energy is also the increment of energy near the velocity of light that accommodates the Lorenz transformation between the classic width of an electron (as a particle) and its Compton-wave solution (Persinger *et al.*, 2008). In other words, the transformation of an electron from the spatial dimension of a particle to that of a wave is equivalent in that domain to the energy associated with a single action potential.

There may be cosmological significance to the value. For example to obtain 10^{-20} J from the gravitational forces between the masses of two ions (K^+ and Na^+) separated at the same distance that produces the membrane and action potentials would require an application (energy is force over distance) equivalent to the width of the universe. Emergent values that approximate the dimensions of the maximum whole unit, the universe, are not unusual in neuroquantology (Persinger, 1999b). For example, in order to obtain the volume equivalence of an electron or proton with a cylindrical width ('a string') of Planck's length (10^{-35} m) the length would be approach the width of the universe (Persinger *et al.*, 2008).

The mean numbers of neurons within a unit volume of human cerebral cortices are ~5 x 10^4 neurons/mm^3 (Pakkenberg and Gundersen, 1997). Assuming an average cortical thickness of 4 mm and the width of a cortical column to be about 0.75 mm (or a thickness of 3 mm and width of 1 mm), then there would be about 15 x 10^4 neurons per column. If the column is considered a functional unit of cerebral energy, then with each neuron generating 7 action potentials per sec (7 Hz) and each action potential generating 1.2 x 10^{-20} J, there would be

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1.26×10^{-14} J per column per sec. The frequency equivalence of this amount, obtained by dividing with Planck's constant, is 1.26×10^{-14} J/6 x 10^{-34} J·s or 0.21×10^{20} Hz. For this calculation 7 Hz was employed because it is within the transition between alpha and theta activity and may be near the centroid for the fundamental mode for the essential harmonic frequencies of cerebrum (Nunez and Cutillo, 1995). The 7 Hz value is not assumed to be a unique integer but rather representative of a narrow range of variations around this frequency as well as the intrinsic derivatives associated within it (Persinger, 1999a).

The equivalent wavelength of this exaHz frequency, assuming an operational velocity of c, is 3×10^8 m/s divided by 0.2×10^{20} Hz or 15×10^{-12} m which is 37 pm, the classic radius of the hydrogen atom or the standing wave distance between a proton and its electron at its lowest energy level. The Bohr magneton, with a magnetic moment of 9.28×10^{-24} A·m^2 or J/T, lays at the basis of quantum mechanics and the concept of entanglement (Aczel, 2002). In fact Bohr (1958) had hypothesized that thinking and consciousness might even involve the extraordinarily weak quantum energies (Persinger and Lavallee, 2010).

There is quantitative support for Bohr's intuition. The magnetic moment of an electron (9.28×10^{-24} J/T) within a magnetic field of 1 pT (10^{-12} T), which is well within the operating range of operating magnetic fields within cerebral space (Persinger, 2011), would be associated with a quantity of 9.28×10^{-36} J. The mass equivalence of this energy is in the order of 10^{-52} kg or 10^{-49} g. This is exactly the order of magnitude of the estimated upper limit of the rest mass of the photon (Tu *et al.*, 2005) and may reflect an important quantitative connection between photons and the essential magnetic field strengths that are strongly correlated with consciousness.

If the holographic principle is operative the unit must reflect the whole and the whole must reflect the unit. According to Park and Lee (2007), the dendrite current can be modelled as a current dipole with a moment of $Q = I_iL$ where I_i is the intracellular current in the dendrite (the unit of Eccles' dendron) and L is the length constant. The dendrite current, initially generated as a post-synaptic current, traverses the dendrite until it reaches the soma. The typical length constant of a dendritic current in the human cortex (about 3 to 4 mm) is typically 0.1 to 0.2 mm (or about the same ratio as between the width of the single ion layer of about 0.6 nm that creates the membrane potential and the 10 nm width of the plasma membrane).

The current moment (Q) associated with a single post-synaptic potential is in the order of 20×10^{-15} A·m (Hämäläinen *et al.*, 1993).

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This means that over the distance of the width of a channel, 0.5×10^{-9} m, the equivalent magnetic moment would be $\sim 10 \times 10^{-24}$ $A \cdot m^2$ which is congruent conspicuously with the magnetic moment of an electron. This convergence would suggest that all channels within this range of width would have the potential to be linked to the orbital rotation of the electron.

De Broglie's Matter Waves, the Heisenberg Uncertainty Principle, and 'Re-entrant' Timing of Cerebral Cortical Fields

Human perceptions of natural phenomena and their properties are defined by the spatial and temporal increments of measurement (Persinger, 1999b). For example, the conspicuous temporal structure of an action potential becomes a straight line when observed with $\Delta t = 10^{-9}$ s rather than 10^{-3} s (1 ms). If the Δt is 28 days the phases of the moon manifest as a single shade of grey. Even the characteristics of matter are no longer correlated as stable properties when the increment of time is less than 10^{-18} s and space is less than 10^{-18} m (that is, smaller than the width of a proton or electron). Human consciousness, with its properties, is similarly constrained. It is not a continuous process or 'stream', although it may be subjectively experienced as such. Instead it must be 'recreated' by dynamic, re-entrant processes (Edelman, 1993).

Because the experience of a percept is within the order of 80 to 120 msec and the duration of 'now', as shown experimentally, is within the 40 msec range, the temporal increments that created this stream or apparent 'continuousness' of consciousness must be shorter. Otherwise, one would experience successive spurts of consciousness like the flicker when watching a motion picture film with less than optimal frame rates. The typical duration of this increment has been considered to be within the 20 ms to 25 ms range, or the classical '40 Hz' band.

Llinas and de Pare (1991) and Llinas and Ribary (1993) have measured 40 Hz waves organized as coherent rostral-caudal fields having phase shifts within the 10 to 20 ms range. This potent candidate for transcerebral global binding of cortical activity depends upon the timing involved with the proposed pathways between thalamic intralaminary cortical input to layer 1 of the cortex mediated through layers 5 and 6 to the intralaminary nuclei (Llinas and Ribary, 1993). Completion time for this 'circuit', assuming average conduction values and distances, would be in the order of 20 to 30 msec and is similar

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to the time required for one completion of the polysynaptic granule cell-CA3-pyramidal neuron-mossy cell-granule cell pathway within the hippocampal formation (Bischofberger *et al.*, 2006).

There are several implications directly relevant to consciousness for this structure-based determination of the 20 to 30 msec 'circuit' time. First, if consciousness in the human sense requires this timing, then the different sized brains that define other animals might not satisfy this condition in the same manner. Secondly, non-carbon systems, such as silicon-based computer pathways, that involve this timing for very complex circuits, might be capable of approaching the critical criterion.

Over the average functional rostral-caudal length of about 11 cm of the cerebral surface, one full phase (cycle) of a 40 Hz ripple would move at 1.1×10^{-1} m/2.5×10^{-2} s or about 4.5 m/s. When such bulk velocity is applied to the resonance formula derived from the velocity divided by the circumference, the typical standing wave or resonance frequency of the cerebral perimeter would be [(4.5 m/s)/0.6 m] between 7 to 8 Hz (Nunez and Cutillo, 1995). Once again this allows global congruence between the modal frequencies associated with memory (the hippocampus) and awareness (the cerebral cortices) and would facilitate the synaptic basis for memory storage within the cerebral cortices (Bear, 1996) through bidirectional hippocampal and cerebral cortical processes. The '40 Hz' superimposition upon hippocampally-derived theta waves indicates this integrity is evident at the most fundamental electrophysiological level.

De Broglie's matter waves or pilot waves, an important concept during the early development of quantum theory, depended upon the quantity of momentum (p) = h/λ where h is Planck's constant and λ is wavelength resulting in units of kg m/s. For an electron or proton with a radius or wavelength of 2.82×10^{-15} m, the momentum is 2.35×10^{-19} kg m/s. If a packet of energy was moving at an average of about 4.5 m/s, such as the rostral-caudal bulk velocity of the electromagnetic field over the cerebral cortical manifold, the energy is about 10^{-20} J. This is the fundamental quantum unit that links the energy of the action potential with the membrane potential. Given the likely range of the bulk velocity around this central value, this is well within the range of the energy generated by a single action potential. That only **one** action potential from one neuron could affect the *global* state of the entire cerebral cortices has been reported by Li *et al.* (2009).

The variant of this equation, Heisenberg's Uncertainty Principle, is expressed conventionally as $\partial p \partial x > h$ where ∂p is the change in momentum and ∂x is the difference or uncertainty of location. If we

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assume complete certainty of the location of an electron with a classical radius of 2.82 x 10^{-15} m then the uncertainty (difference) of momentum is $\partial p = 6.624 \times 10^{-34}$ J s/2.82 x 10^{-15} m or 2.35 x 10^{-19} kg m/s. At a bulk velocity of about 4.5 m/s for transcerebral magnetic fields, the energy would be 10^{-20} J.

The solution could suggest that at this velocity the uncertainty would be the major correlate of consciousness and would support the argument that consciousness is an aggregate of the individual action potentials, $\Sigma n = n$. Consequently the property of the cerebral whole based upon an elementary unit, the electron or proton, reflects the energy of the functional unit, the action potential, of a single neuron. These two fundamental particles do not share mass characteristics, but they could share values for drift velocity which involves the actual movement of the physical unit rather than the energy. Drift velocity is defined as $(J/kg)^{1/2}$ (energy/mass). If the proton is intimately involved with the cohesive factors associated with the binding state for consciousness, then its intrinsic velocity within cerebral space should approximate the bulk velocities associated with the presumed reentrant processes associated with consciousness. This should also emerge at the level of the single ion channel.

If we assume a 0.2 μV change associated with a single ion channel (Kandel *et al.*, 2000), the energy exerted on a charge is this voltage multiplied by 1.6 x 10^{-19} A s or 0.5 x 10^{-25} J. The square root of this value divided by the mass of a proton (1.6 x 10^{-27} kg) results in a velocity of about 4.5 m/s. This value, divided by a typical human skull circumference of 60 cm yields a value of 7.5 Hz and occupies the band for the fundamental cerebral resonance (Nunez and Cutillo, 1995). This convergence with the Schumann resonance of the earth-ionosphere system, particularly when the remarkably similar values for phase shifts for both sources of resonances are considered, suggests the potential for a near-continuous interaction between the aggregate of all human brains and this unique, narrow-band geophysical frequency; more precise calculations indicate the phase shift would potentially precede those associated with consciousness by a duration in the order of 10 ms.

The time required for a proton to move at 4.5 m/s across a membrane of 10 nm is about 2.2 x 10^{-9} s. During the 1 ms associated with an action potential the numbers of protons (H^+) moving through a channel, as components of ions or water, would be about 1 x 10^{-3} s divided by 10^{-9} s/proton or 10^6 protons. This number is within an order of magnitude for the estimated number of cations that move through these < 1 nm width 'cylinders' of intramembrane conductive

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organizations of protein. When multiplied by the unit charge the net current would be within a factor of 10 of the 1 pA typically found across many membranes. If the critical factor is the (absolute) numbers of protons, then the aggregate of protons that defines the atomic weight of either Na^+ or K^+ would compensate for this discrepancy.

The ubiquitous presence of voltage-gated proton (H^+) channels in membranes and the fact that proton permeability for membranes is up to ~10^{-2} cm/s while the permeability of other cations is about a billion times slower (DeCoursey, 2003) indicates that 'free' protons may be a source of convergence for creating $\Sigma n = n$. H^+ has a five-fold greater conductivity in water even when compared to potassium. Estimates suggest there must be ~10^3 more voltage-gated proton channels than other ion channels such as the traditional sodium and potassium forms. The actual current magnitude per proton channel is pH-dependent and can range from fA to pA. Unlike other ion channels, voltage-gated proton channels do not inactivate but diminish conduction as a result of increased internal pH from the cellular efflux of H^+. In other words, like 'consciousness' in a general sense, the values fluctuate continuously between a wide band of possibilities.

The relationship between the electromagnetic properties of the ion channel and essential quantum energies, such as 10^{-20} J, is supported by classical interpretations. The magnetic dipole strength is defined as $B_{z>a} = [(\mu_o Ia^2)/zr^2]$ where z is the length of the 'cylinder' and 'a' is the width. Assuming a width of 1 nm and a length of 10 nm for a pA current channel, the magnetic field strength is in the order of 10^{-10} T, or the upper picoTesla range within which the cerebral functions associated with consciousness operate. Assuming an intrinsic 7 Hz variation which has an energy (7 Hz*Planck's constant) of 4.6 x 10^{-33} J and the fact that $A \cdot m^2$ = J/Tesla, a 10^{-10} T field would be associated with a magnetic moment of about 9 x 10^{-24} $A \cdot m^2$, the Bohr magneton.

If the protein vortex that defines the prototypical ion channel is assumed to have a width of 1 nm and a length (the width of the plasma cell membrane) of 10 nm, then the volume is 7.85 x 10^{-21} cc (to make concentration of molarity easier) or 7.85 x 10^{-24} L. Because water is 55 M and there are 6.023 x 10^{23} molecules per mole, then a channel will contain about 260 molecules of water. With the typical concentration of hydronium atoms (H_30+) that contain the mobile proton around 40 x 10^{-9} M, there would only be about 10^{-5} hydronium molecules. However, the lifetime for each hydronium molecule is only 10^{-12} s (1 ps). This means there would be 10^7 proton displacements per second which is equivalent to the numbers of K^+ or Na^+ ions that tra-

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verse a single channel per second. During a sustained outward H^+ current of 10 pA amplitude about 10^7 H^+ leave the cell each second.

The mobility of H^+ in water is 3.6×10^{-3} $cm^2/V \cdot s$ (DeCoursey, 2003). Within a typical environment of 70 mV for the duration of an action potential (1 ms), the mobility would expand to approximate the radius of neuronal soma. With a diffusion constant of about 8.7×10^{-5} cm^2/s, the expansion from a punctate energy within 0.3 ms, the typical diffusion time for a neurotransmitter across the synapse, would be 2.6×10^{-8} cm^2 whose linear distance would be about 1.6×10^{-4} cm (1.6 μm), the width of a synapse. This value is also within measurement error of the optimal input velocity (2 ± 0.4 μm/ms) to produce peak EPSP (excitatory post-synaptic potentials) in dendrites of cortical neurons when discriminating temporal sequences (Branco *et al.*, 2010).

The magnetic moment of a proton is 2.79 nuclear magnetons (μ_N) or about 15×10^{-27} J/T. Within an intensity of 10^{-6} T (1 μT, the range of strength of our experimental applications of magnetic fields), the energy would be 15×10^{-33} J. This is equivalent, when divided by Planck's constant of 6.6241×10^{-34} J·s, to a frequency within the 20 Hz to 30 Hz range. With fluctuations of the intensities of the applied magnetic field within a range of 0.3 to 3, the critical range (4 Hz to 40 Hz) for intercalation between memory and consciousness would be accommodated. When all of these characteristics are considered, protons have the potential to be the unit whose properties are reflected within the whole.

The connecting role of the membrane channel, which meets topological criteria for a solenoid, is additionally supported by classical approaches that suggest there is continuity between the numbers of elements and the dynamics reflected as number of 'turns' in this vortex. Reluctance ($R = d/\mu A$) and inductance ($L = N^2/R$), where d is the length, A = area, and N is the number of turns in this 'solenoid', can be integrated such that the value for N would be $v[(Ld)/(\mu A)]$. Assuming an inductance of 10^4 Henrys, there would be about 10^7 turns. This particular inductance value would be required in order for the energy stored in a solenoid, defined by $J = 1/2\ L*I^2$, to be equivalent to 10^{-20} J. This is the value that relates energies across levels of organization.

Even the solution for drift velocity (v_d), which is the motion for the unit associated with the energy rather than the energy itself, from classical approaches matches the quantitative solution. $V_d = I/(A \cdot n \cdot e)$ where A is the cross-sectional area of the channel, n equals the number of electrons in the volume, and e is unit charge. With 10^{-12} A per channel divided by the 10^{-18} m^2 cross-sectional area of the channel and

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10^{33} charges/m^3 (10^7 ions/10^{-26} m^3 of channel volume), the drift velocity through the membrane would be ~10^{-8} m/s or 10 nm/s, which is remarkably similar to the actual measurement of the transverse velocity of K^+ through a membrane. In comparison the movement of K in water is about 10 cm/s.

A Convergent Solution for the Whole and the Unit

If $\Sigma n = n$, then its manifestation should be recurrent within all bulk solutions and valid dimensional analyses whose resultant involves neuronal energy. For example, the resultant aggregate unit for the square root of the product of magnetic field strength (B, in Tesla), voltage (V), cross-sectional area (m^2), frequency (1/s), and the sum of the total charge-squared for the volume in question is energy. For the total charge-squared we assumed there are 40 x 10^9 neurons in the cortices, with 5 x 10^8 functional charges per cell and 1.6 x 10^{-19} A·s/charge or 3.2 A·s.

The operational strength of the magnetic field associated with consciousness and the integrated volume within the brain generally and the cerebral cortices in particular is in the order of 40 x 10^{-12} T and the functional voltage is about 10 μV (10^{-5} V). An average surface area of the cerebral cortices is 2.8 x 10^{-2} m^2. If we assume 7 Hz to be a representative value for the operating frequency of the cortical manifold, then the total energy would be 26 x 10^{-9} J. In comparison, a direct solution by assuming 2.1 x 10^{-20} J per action potential and 40 billion neurons firing at an average frequency of 7 Hz would be 6 x 10^{-9} J. The powers of ten are identical for solutions based upon summing the individual units (the neurons's action potential) or calculating the quantity for the whole. At 6 times 7 Hz (the '40 Hz' range) and with fewer neurons the value of the total energies from the two origins would converge.

$\Sigma n = n$ is more conspicuously evident when energy is derived from the same units by which neuroscientists describe cerebral tissue. J (energy) is the square root of the product of (V^2*B*$Coulomb^2$) where B is the band width of electroencephalographic activity. With the typical value of 50 x 10^{-6} V^2/Hz for a band of 100 Hz and 2.56 x 10^{-38} A^2s^2, the solution is the square root of 1.28 x 10^{-40} J^2 or about 1 x 10^{-20} J. With inclusion of a 500 Hz range of cerebral activity, which would include the fast transients, the energy would be within the 1 to 2 x 10^{-20} J range, even with assumptions of less power, e.g. 10 uV^2/Hz. Once again, the whole is equal to the element and the element is equal to the whole.

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The magnetic energy stored within the cerebral volume can be calculated by $(B^2/4\pi\mu)*m^3$. Assuming 10^{-11} T (10 pT) as within the range of the operating intensity of the entire cerebral cortices (the volume of the cortices is ~0.44 x the volume of the cerebrum) the energy would be about 2 x 10^{-20} J. Consequently, the energy storage within the space occupied by an increased magnetic field intensity of about 10 pT would be congruent with the energy associated with a single action potential.

Can We Experimentally Influence the Whole Through the Unit?

We (Persinger *et al.*, 2010a) have been applying transcerebral magnetic fields with complex temporal patterns in order to affect the neural substrates of the processes associated with consciousness, thought, and experience. The average maximum increased magnetic field intensity is about 5 μT (50 mG). The energy storage from an applied field of 5 μT within the cerebral volume of 1.1 x 10^{-3} m^3 would be this value times $[(5 \times 10^{-6} T)^2]/[2*12.56*10^{-7} N/A^2]$ multiplied by 0.44 (the estimated average ratio of the volume that is cortices). This value is about 6 x 10^{-9} J. We have found that total energy within the cerebral volume is more related to correlated experiences than traditional models that employed Faraday's induction currents or the concept of Lorentz's forces. Even the traditional critique that weak magnetic fields cannot be effective because their associated molecular energies are below those predicted by the Boltzman kT boundary ignore the capacity for certain types of complex magnetic fields to utilize energy from 'random' or stochastic resonance to couple cellular activity. The 'kT constraint' is only applicable to systems near thermal equilibrium (Cifra *et al.*, 2011).

Each action potential is associated with an energy of 10^{-20} J. Assuming there are between 10^{10} and 10^{11} neurons in the cerebral cortices with an average firing rate of about 10 (10^1) Hz, the total energy associated with the primary correlate of experience, the action potential, would be between 10^{-9} and 10^{-8} J. In other words, the applied fields that produce the very significant changes in specific experiences associated with changes in cognitive states and correlative quantitative EEG profiles generate bulk energies that are equivalent to those associated with the electromagnetic energies of cortical neuronal function.

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The Field-to-Field Interaction

The quantitative convergence between the energy contained within our applied magnetic fields and that generated by the EM component of neuronal activity indicates a quantitative threshold is present. However, to interact with the cerebral hologram the applied magnetic field should interact with the *boundary* of the hologram. Applications of transcerebral magnetic fields across the brain at the level of the temporal lobes have been shown to produce reliable changes in sensory and cognitive experiences.

Quantitative EEG (QEEG) data indicate that a sequence of stimulation by 5 μT fields with a 10% greater intensity over the right hemisphere is associated with greater convergence of theta activity between the left temporal and right prefrontal region, while subsequent bilateral stimulation is associated with greater right-to-left temporal coherence. These two experimental conditions and quantitative EEG patterns are associated with reports of out-of-body experiences and the sensed presence, respectively (Persinger *et al.*, 2010a; Saroka *et al.*, 2010).

However, application geometries that create more cerebrally inclusive fields that rotate in a counterclockwise direction around the skull, such that interference patterns are more likely to be generated within the right hemisphere between the rostral accelerating circumcerebrally applied fields and the rostral-to-caudal phase modulations of 20 msec within the cortical manifold, produce more profound changes in consciousness. Accelerating or de-accelerating magnetic fields with angular values for variable velocity and acceleration are associated with profound effects on consciousness and the awareness of this state (Tsang *et al.*, 2004; Booth and Persinger, 2009). Our recent research has shown that aggregates of cells or human brains maintained in the dark and separated at non-conventional distances respond with biophoton emission if the other aggregate of cells or human brains share the same accelerating/decelerating, rotating magnetic field when stimulated with light (Dotta *et al.*, 2011). A similar effect was shown with electroencephalographic activity (Persinger *et al.*, 2010b).

The essential experimental question is how do we access and interact with the boundary of the holographic field of the cerebrum that is associated with consciousness by first accessing the essential unit that is reflected reciprocally within the whole? We have assumed, similar to the concepts of Casimir forces (Bordag *et al.*, 2001), that a field is composed of quantized points with some Δs (increment of space) that

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exhibits a real value that determines resolution of the information and within a fixed volume (such as the brain) the amount of information that can be represented. The Δs, the width of a synapse or the dendritic spine, is about 1 μm. There are about 10^{13} of these units in the cerebral cortices.

The unique spatial range of the synapse produces Casimir solutions that are consistent with the hologram interpretation. The quantitative value for this force is derived from $(\pi^2/240)*(\hbar c/a^4)*S$, where ħ is the modified Planck's constant, c is the velocity of light, 'a' is the width (10^{-8} m) of a synapse, and S is the linear width of a synapse (10^{-6} m). The Casimir force for this particular set of spatial parameters is $\sim 10^{-11}$ N. However when this force is applied over the width of a channel, 10^{-9} m, the resulting energy is $\sim 10^{-20}$ J. This means that the same increment of energy that is responsible for the membrane potential when expressed from electrical forces, and that would require a distance equal to the width of the universe if derived from gravitational attraction between key ions, is also the solution for one of the most fundamental forces in the universe when applied to the ion channel.

The application of the external magnetic field creates a boundary that polarizes the cerebral field such that particles would be created from the vacuum (Bordag *et al.*, 2001). Energy is transferred by the external field to virtual particles thus transferring them into real ones that can emerge within the cerebral holographic field and hence modify consciousness. There is no effect with static boundaries. When the boundary conditions change as a function of time, there is particle creation in addition to the force over distance or energy.

A circularly rotating magnetic field, which is technically always accelerating, with the addition of temporal derivates created by successive shifts in the angular velocity, are the optimal application of this concept. At present our primary application geometry is an array of eight solenoids equally spaced around the cerebrum at the level of the temporal lobes. When the solenoid over the left prefrontal region is activated for 20 ms and then 2 ms is added or subtracted from each of the next 7 solenoids as the magnetic field rotates around the cranium, marked alterations in consciousness occurs (Booth and Persinger, 2009; Cook *et al.*, 1999).

More dense arrays of 64 solenoids or 128 solenoids equally distributed over the surface of a hat or helmet produce finer and finer 'punctate' magnetic fields that are continuously activated and deactivated by orchestrated computer programs. These 'scintillating' rotating stimulations produce an aggregate field that meets the criteria for the definition of an applied, non-static field. The quantized Δs emerges

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within the boundary where repulsion ('cancellation') occurs for adjacent same-polarity fields or enhancement occurs for opposite-polarity fields. If our hypothesis is correct, as the numbers of solenoids (spatial density) increase and their diameters decrease the Δs of the transiently localized 'cancellation' or reciprocal 'enhancement' will approach the 1 μm unit to which the whole cerebral field is mapped and upon which each unit is projected.

The second major technical requirement is the appropriate timing or point duration for the computer-controlled voltage (–5 to +5 V) activation of each solenoid. We have found that the optimal duration for each punctate activation for a solenoid is between 1 ms and 3 ms. This particular optimal Δt occurs for cells as well as non-human organisms. Although the similarity to the duration of the action potential (the fundamental source of the digital sequences and 'language of the living brain') is obvious, there may be a more fundamental explanation that couples the process to both holographic phenomena and to the proton.

The human brain is matter that occupies space. At the level of the atom the proportion of matter that occupies space is about one part per trillion. Below the Δs of 10^{-15} m, the width of a proton or electron, phenomena are no longer organized as matter. Between this Δs and the smallest increment quantifiable from basic units, 10^{-35} m (Planck's length), there are 20 orders of magnitude. When the expansion of space is considered by employing Hubble's constant between 50 and 100 km/s/Mparsec (3.1×10^{22} m), the temporal solutions for the resultant division range from 1.6×10^{-18} s^{-1} to 3.2×10^{-18} s^{-1}. According to Persinger and Koren (2007), the velocity of expansion for any matter occupying space would be this value multiplied by the width of the space.

The length of a proton is assumed to be 2.6×10^{-15} m (twice the Compton radius). For a proton the velocity of expansion, based upon the median value for Hubble's constant, would be 8.3×10^{-33} m/s. The time to expand one Planck's length would be 1.6×10^{-35} m divided by 8.3×10^{-33} m/s or about 3 ms. We have suggested this solution is not coincidence for the importance of the proton in cerebral holographic phenomena and for this origin in the production of a holographic universe of which the proton could be the essential unit.

When either the smallest length (Planck's length) or the longest length (width of the universe) is placed into the same equation, the time required for the width of the universe to expand one Planck's length would be Planck's time (10^{-44} s) while a single Planck's length (10^{-35} m) would require the age of the universe to expand one unit.

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These conditions where the temporal properties of the unit equal the whole would satisfy the definitions of an intrinsic hologram.

When these calculations and assumptions are integrated conceptually and technically, the most optimal means of experimentally interfacing with the cerebral holographic electromagnetic field associated with consciousness would involve a changing circumcerebral pattern of about 1 μT magnetic fields generated by the appropriate density of very small solenoids over the cranial surface. The base temporal increment of activation for each solenoid would be between 1 and 3 ms. This space-time configuration would, if our hypothesis is valid, allow convergence between the bulk electromagnetic properties of the cerebral cortices and the intrinsic distributions of protons that allow the holographic condition to occur. However, like all living systems that operate according to the central limit theorem (the basis of normal distribution), the application parameters will involve quantitative ranges that must accommodate the individual equation.

Cerebral Epiphenomena and Future Implications

The consistency of the $\Sigma n = n$ concept described in this manuscript could reflect a fundamental property of the universe or the unique organizational property of the human brain that determines or strongly influences cognitive processes associated with numerical concepts and mathematical solutions. If the former is correct, then a universal source to 10^{-20} J and to photon correlates of cerebral activity would be relevant to future considerations concerning human consciousness.

As reported previously (Persinger, 2009), the estimated mass of the universe, about 10^{52} kg, can be obtained by taking the estimated pressure (proton density*c^2) and setting it equal to the gravitational constant, G. For the units to be commensurate an intermediate 'tensor' is required that is $[10^{104}\ m^4]/[10^{104}\ kg^2]$. The total force of kg m/s^2 within the universe would 10^{52} kg*10^{26} m (its approximate width)*10^{86} s^{-2} (Hz^2) which is effectively the inverse of Planck's time or the intrinsic 'Zwitterbewugen', 'jitter', or zero-point fluctuation (Puthoff, 1989) of the smallest unit of space; this value is 10^{164} N.

If we assume the smallest unit is Planck's length of 10^{-35} m (and assume cubic shapes for simplicity), then the volume would be 10^{-105} m^3, and within a universe with a volume of ~10^{78} m^3 there would be 10^{183} of these essential 'voxels'. This means there would be 10^{164} N/10^{183} 'voxels' or 10^{-19} N per basic unit. If this force is applied across the most fundamental wavelength in the universe, the hydrogen

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(which composes 90% of the universe) band of 21 cm, then the equivalent energy is about 10^{-20} J.

The convergence with photon energies becomes apparent when the total numbers of photons (10^{104}), with an estimated rest mass of about 10^{-52} kg, is found for the total mass of the universe, 10^{52} kg. Both the solutions for general relativity (Persinger, 2010b) and energy-mass equivalence indicate that the total energy within the universe would be ~10^{69} J which would mean there is about 10^{-35} J per photon. Again this value is remarkably proximal to the value for Planck's constant.

However, the extended solution is more revealing. With J = kg m^2/s^2 then s = $\sqrt{}$(kg m^2)/J. So with the universe's mass of 10^{52} kg, a cross-sectional area of 10^{52} m^2, and the total energy of 10^{69} J, the total time is $\sqrt{}10^{35}$ s^2 or 3 x 10^{17} s, the estimated age of the universe. The solution reiterates the frequently stated inference that photons do not 'experience' time and that the Δt for the photon now is the same as it was more than 10 billion years ago. This solution more easily accommodates a fundamental assumption in quantum philosophy (Horgan, 1992) that changing the parity of a photon now influences its 'partner' at the beginning of the universe.

The more important implication for the implicit premise of the present argument involves the convergence of the solution at the level of the cell membrane and its channel. If the total number of 'voxels' of Planck's length is 10^{183} and there are 10^{104} photons in the entire universe, then large numbers (10^{79}) of these voxels will be 'cohesively' bound by one photon or its equivalent. With a volume of 10^{-105} m^3/'voxel'*10^{79} voxels/photon there would be the equivalent of 10^{-26} m^3/photon. The cube root for that value is between 1 nm, the width of a membrane channel, and the width of a plasma membrane. This could indicate that the emergence of a single photon from a membrane might relate to the information within those large numbers of increments 'wrapped' within structural dimensions of space.

Assuming these solutions are not intrinsic limitations reflected from Gödel's incompleteness theorem or the reflective constraints of the human brain's structure, 1) the connective solutions between the time for a proton to expand one Planck's length and the duration of an action potential, 2) the representation of a photon's 'cohesiveness' within the space of a membrane and membrane channel, and 3) the presence of 10^{-20} J at both membrane and universal boundaries may suggest that the hologram concept may be more relevant to understanding consciousness than simply a convenient metaphor.

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